

Forward Kinematics. *unique Solution*

$$\text{d} \mathbf{T}_i \rightarrow \begin{bmatrix} \mathbf{f} \\ \mathbf{R} \end{bmatrix} \xrightarrow{\substack{\text{position} \\ \text{orientation}}} \mathbf{T}_{EE} = \begin{bmatrix} \mathbf{R} & \mathbf{d} \\ \mathbf{0} & 1 \end{bmatrix}$$

$\mathbf{h}_{ij} \rightarrow \text{function of } \mathbf{f}_i(\mathbf{q}_i)$ Kalmann

Inverse Kinematics (multiple solutions)

given desired pose

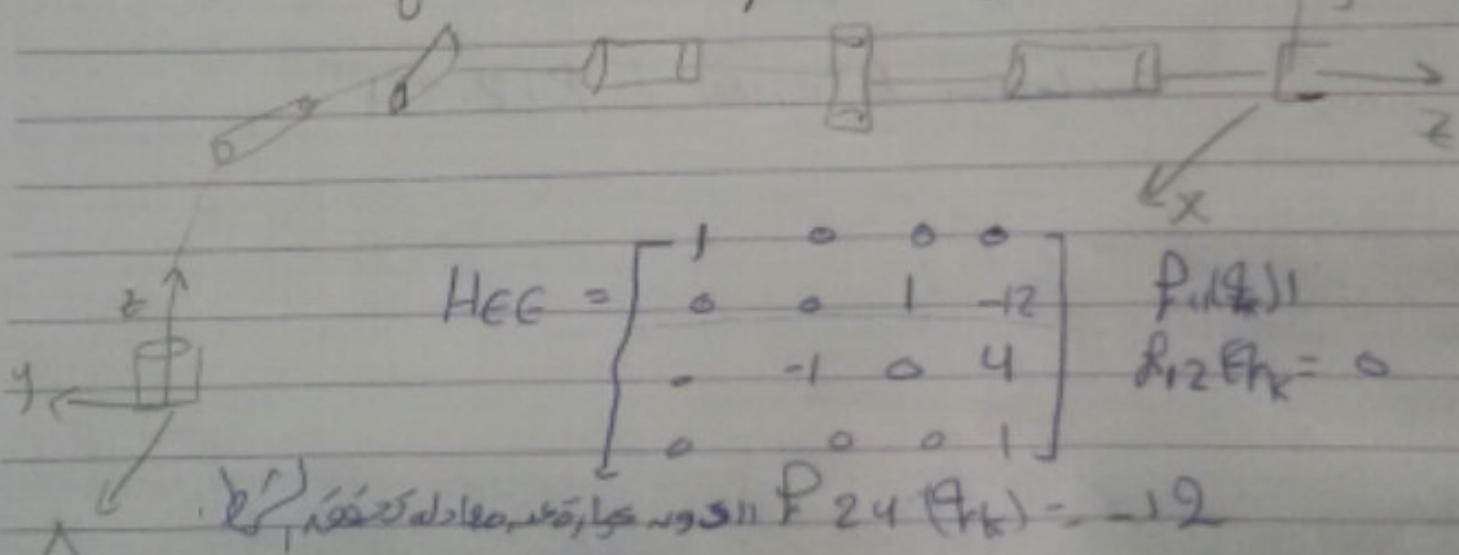
$$\mathbf{q}_k = \mathbf{f}_n(\text{pose})$$

$$\text{pose} \xrightarrow{\substack{\mathbf{3D} \\ \mathbf{J}}} \mathbf{q}_k$$

given $\mathbf{H}_{EE}^{\text{desired}}$
End effector

model from solving 12 nonlinear eqns

$\mathbf{h}_{ij} \rightarrow \text{certain value}$



$$\text{Solving for } \mathbf{q}_k \quad \mathbf{f}_{24}(\mathbf{q}_k) = -12$$

12 nonlinear equations

Solve for position \leftarrow DOF

using \rightarrow

1- Closed form

independent variables \rightarrow dependent variables

$$T_K = J_K(P_{-30})$$

1- given form

trigonometric

2- cell by using all joints

of msg frame is \rightarrow \rightarrow \rightarrow

Analytical method
algebraic

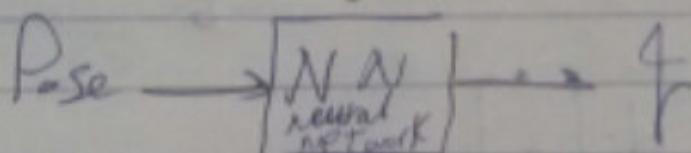
Geometric

- also called
- simple Kinematic Chain
- Robot Geometry

2- Numerical method

iteration uses given in \rightarrow Forward Kinematics
answer

3- Artificial intelligence



ANFIS is helped

?

د. تحاصل على المعلمات المطلوبة
بتقنية التفكيك

Kinematic Decoupling: Geometric approach

6 Dof manipulator
spherical wrist

Given

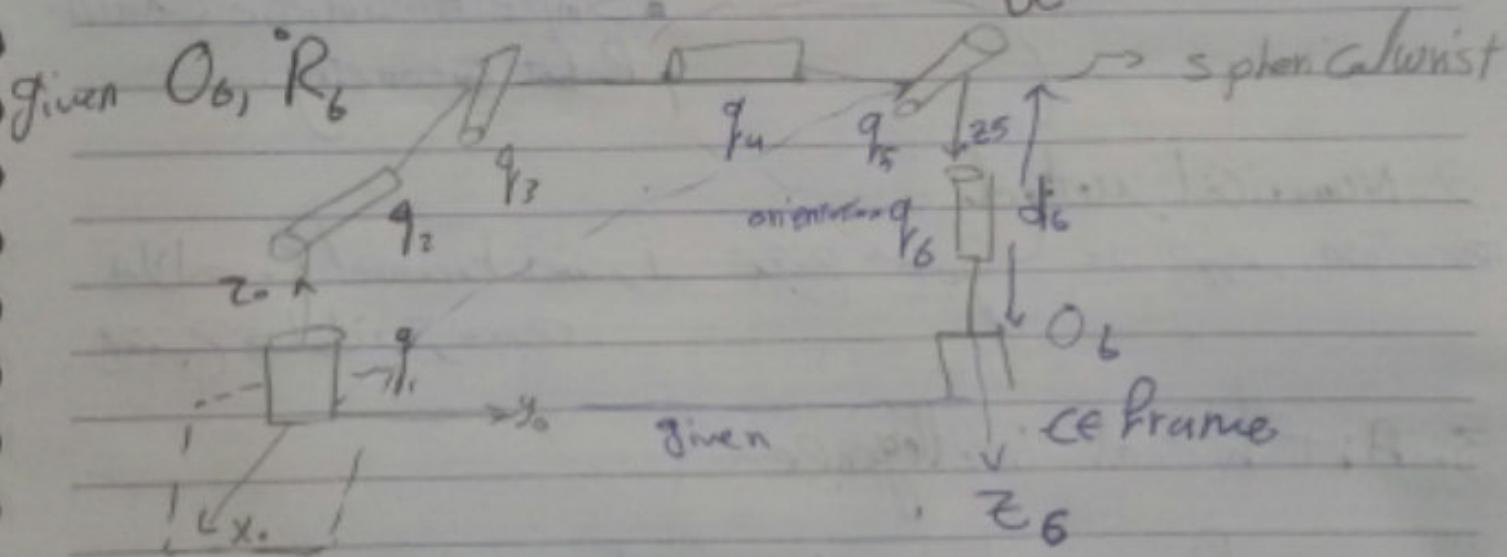
Robert

wrist Center = $f(q_1, q_2, q_3)$

orientation = $f(q_4, q_5, q_6)$

spherical wrist angles

wrist center
OC



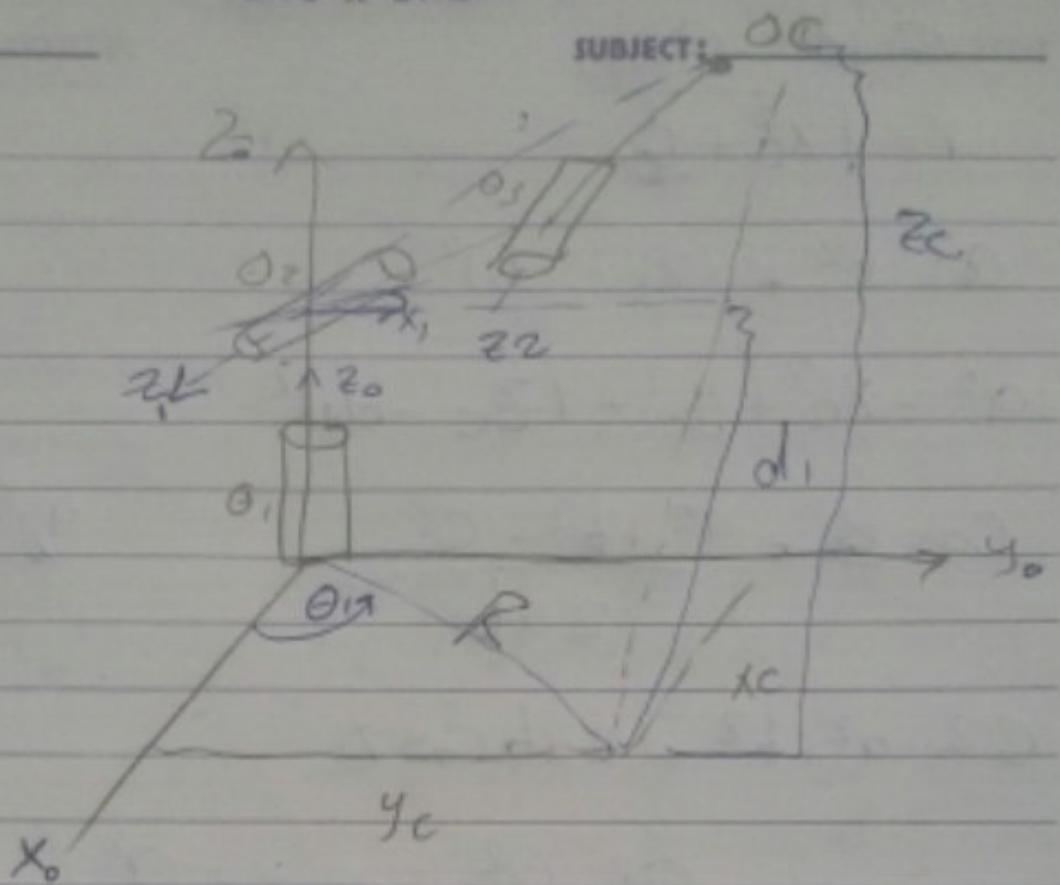
$$\overset{\circ}{O}_b = \overset{\circ}{O}_C + \overset{\circ}{R}_b \overset{\circ}{d}_s \begin{bmatrix} \vdots \\ \vdots \end{bmatrix}$$

$$\overset{\circ}{O}_C = \overset{\circ}{O}_b - \overset{\circ}{d}_s \overset{\circ}{R}_b \begin{bmatrix} \vdots \\ \vdots \end{bmatrix} \rightarrow ①$$

$\overset{\circ}{O}_C, \overset{\circ}{y}_C, \overset{\circ}{z}_C$

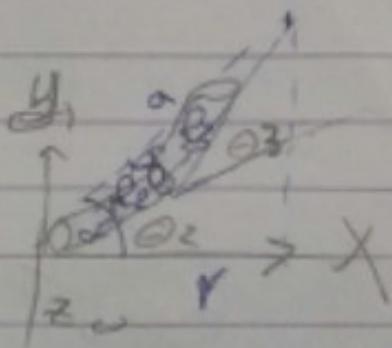
DATE: _____

SUBJECT: OC



θ_1 → manipulator يعطيه اتجاه
الزاوية θ_1 حول الأفق

$\theta_2 \rightarrow$



$$\tan \theta_1 = \frac{y_c}{x_c}$$

$$\theta_1 = \tan^{-1} \left(\frac{y_c}{x_c} \right) \rightarrow ②$$

$$= \arctan \left(\frac{y_c}{x_c} \right) \rightarrow \text{matlab}$$

تراس الرابع وستة احداثيات بالغير الدائري

DATE: 10/10/2022

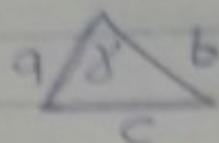
SUBJECT: _____

$$r = \sqrt{x_c^2 + y_c^2}$$

$$a^2 = r^2 + (z_c - d_w)^2$$

$$a^2 = x_c^2 + y_c^2 + (z_c - d_w)^2$$

$$\cos \delta = \frac{a^2 + b^2 - c^2}{2ab}$$

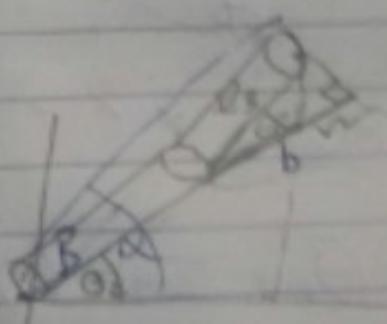


$$c^2 = a^2 + b^2 - 2ab \cos \delta$$

$$\cos \delta = \frac{l_2^2 + l_3^2 - c^2}{2l_2 l_3}$$

"Cosine law"
based on triangle

$$\theta_3 = 180 - \delta$$



$$\cos \theta_3 = \frac{l_2^2 + l_3^2 + x_c^2 + y_c^2 + (z_c - d_w)^2}{2l_2 l_3}$$

$$b = l_3 \cos \theta_3$$

$$\beta = \omega^{-1} (l_2 + l_3 \cos \theta_3)$$

DATE: _____

SUBJECT: _____

$$\theta_2 = \tan^{-1} \frac{z_c - d}{\sqrt{R_c^2 + Y_c^2}} - R$$

∞

$$\dot{R}_b = \overset{\circ}{R}_3 \overset{\circ}{R}_6$$

$$\overset{\circ}{R}_6 - (\overset{\circ}{R}_3)^{-1} \overset{\circ}{R}_6$$

$\hookrightarrow \theta_4, \theta_5, \theta_6$
 using Euler Parameterization.
 substitute by $\theta_b, \theta_2, 3$